علوم شناختی و ریاضیات

- J. Piaget ***The Child's Conception of Number***, 1952
- N. Chomsky ***Language and Mind*** (3rd edition), 2006
- S. Carey ***The Origin of Concepts***, 2009

- S. Carey and E. Spelke `Domain-specific knowledge and conceptual change' in ***Mapping the Mind*** (eds. L Hirschfeld and S. Gelman), 1994
- M.D.Hauser, N.Chomsky and W.T.Fitch `The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?' in *Science* 298, 1569-1579, 22 Nov.2002

- An elementary fact about the language faculty is that it is a system of discrete infinity, rare in the organic world. Any such system is based on a primitive operation that takes objects already constructed, and constructs from them a new object: in the simplest case, the set containing them. Call that operation Merge.

  …

- With Merge available, we instantly have an unbounded system of expressions. The simplest account of the “Great Leap Forward” in the evolution of humans would be that the brain was rewired, perhaps by some slight mutation, to provide the operation Merge, at once laying a core part of the basis for what is found at that dramatic moment of human evolution …

- The most restrictive case of Merge … yields the successor function, from which the rest of the theory of natural numbers can be developed in familiar ways. That suggests a possible answer to a problem that troubled Wallace in the late nineteenth century: in his words, that the "gigantic development of the mathematical capacity is wholly unexplained by the theory of natural selection, and must be due to some altogether distinct cause,"…. One possibility is that the natural numbers result from a simple constraint on the language faculty …Speculations about the origin of the mathematical capacity as an abstraction from linguistic operations are not unfamiliar. There are apparent problems, including dissociation with lesions and diversity of localization, …

- Chomsky, *Language and Mind* (3rd ed), pp.183-4

- Why did humans, but no other animal, take the power of recursion to create an open-ended and limitless system of communication? Why does our system of recursion operate over a broader range of elements or inputs (e.g., numbers, words) than other animals? One possibility, consistent with current thinking in the cognitive sciences, is that recursion in animals represents a modular system designed for a particular function (e.g., navigation) and impenetrable with respect to other systems. During evolution, the modular and highly domain-specific system of recursion may have become penetrable and domain-general. This opened the way for humans, perhaps uniquely, to apply the power of recursion to other problems. This change from domain-specific to domain-general may have been guided by particular selective pressures, unique to our evolutionary past, or as a consequence (by-product) of other kinds of neural reorganization.

- Hauser, et al, *Science* 2002

(Core Cognition) شناخت درونگاهی

- Advocated by some cognitive scientists, notably Susan Carey and Elizabeth Spelke.
- A capacity between perception and conceptual thinking (similar to `*wahm*' enunciated by Ebne Sina)
- Learning devices developed early in life in specific modules and persisting permanently unlike conceptual beliefs
- Some are shared by other animals including certain object and behavioral recognitions
- Two capacities for dealing with small numbers seem to be core cognitions

Quotation from Carey's *Origin of Concepts* (1)

- … cognition of humans, like that of all animals, begins with highly structured innate mechanisms designed to build representations with specific content. I call these real-world content domains "core domains," and I call the mental structures that represent them "core cognition". ….core cognition has rich integrated conceptual content. By this I mean that the representations in core cognition cannot be reduced to perceptual or sensory-motor primitives,…

Quotation from Carey's *Origin of Concepts* (2)

- Core cognition is elaborated during development because core cognition systems are learning devices, but it is never rendered irrelevant. It is never overturned or lost, in contrast to later developing intuitive theories, which are sometimes replaced by subsequent, incommensurable ones….systems of core cognition are domain-specific learning devices some core cognition (including that of objects) is shared by other animals. At least some early developing cognitive systems in humans have a long evolutionary history…

علم مغز و ریاضیات

- S. Dehaene ***The Number Sense***, 1997, 2011
- B. Butterworth ***Mathematical Brain***, 1999

- S. Dehaene and J.-P. Changeux `Development of Elementary Numerical Abilities: A Neuronal Model,' *J. Cognitive Neuroscience* 5(1993):4, 390-407
- M. Amalric and S, Dehaene `Cortical circuits for mathematical Knowledge: evidence for a major subdivision within the brain's neural network', *Phil. Trans.R.Soc.B* 373: 2016.05.15, 1-9
- J. Kulasingham, et al `Cortical Processing of Arithmetic and Simple Sentences in an Auditory Attention Task,' *J.Neuroscience*, September 22, 2021; 41(38) 8023-8039

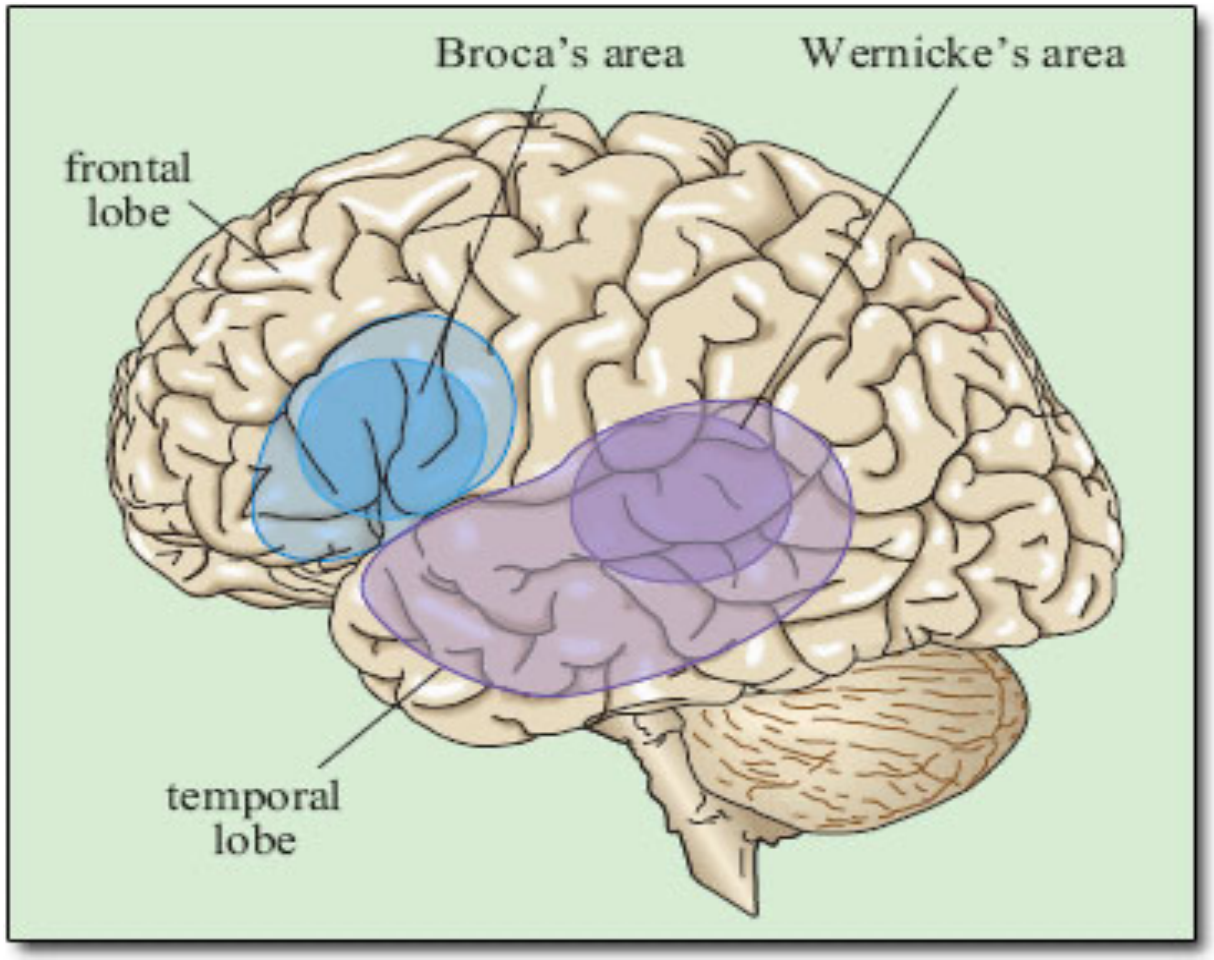
Language vs Mathematical Semantics

Is mathematical language similar to natural language? Are language areas used by mathematicians when they do mathematics? And does the brain comprise a generic semantic system that stores mathematical knowledge alongside knowledge of history, geography or famous people? Here, we refute those views by reviewing three functional MRI studies of the representation and manipulation of high-level mathematical knowledge in professional mathematicians …

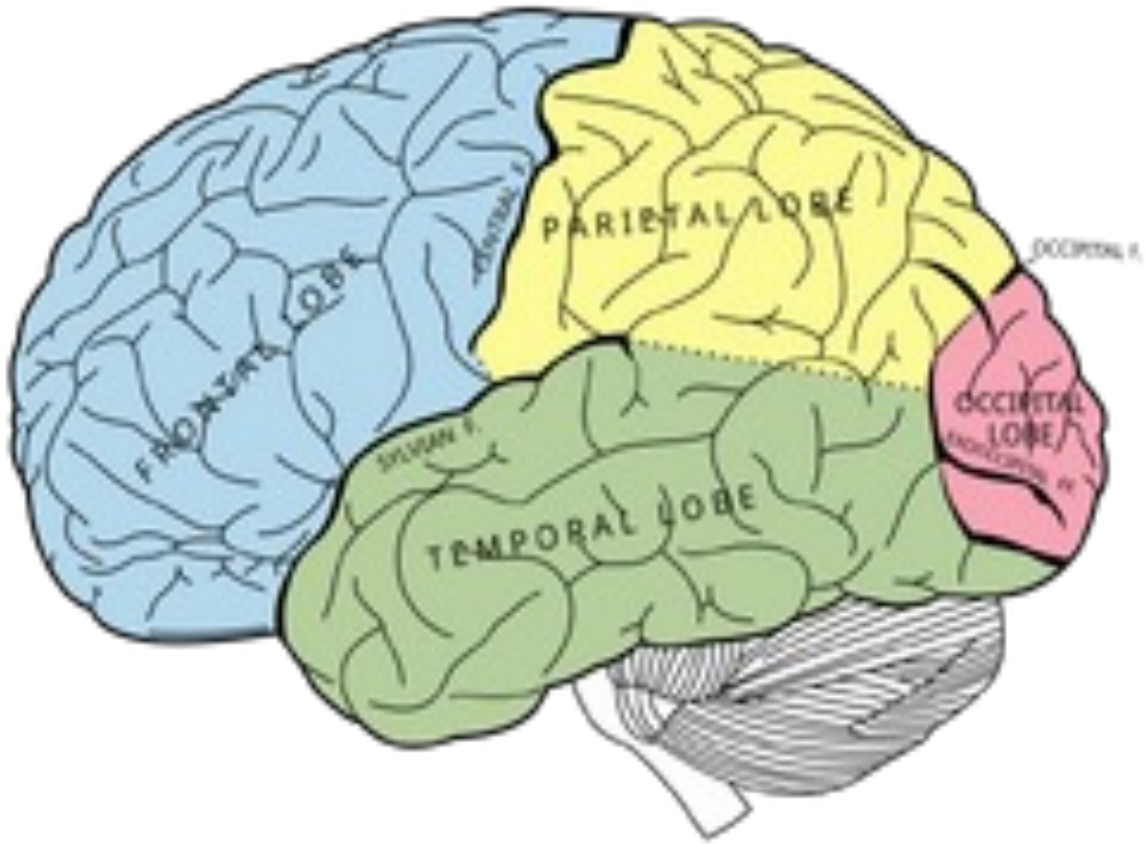
… brain activity during professional mathematical reflection spares perisylvian language-related brain regions as well as temporal lobe areas classically involved in general semantic knowledge. Instead, mathematical reflection recycles bilateral intraparietal and ventral temporal regions involved in elementary number sense. Even simple fact retrieval, such as remembering that ‘the sine function is periodical’ or that ‘London buses are red’, activates dissociated areas for math versus non-math knowledge. Together with other fMRI and recent intracranial studies, our results indicated a major separation between two brain networks for mathematical and non-mathematical semantics.

- M.Amalric and S. Dehaene

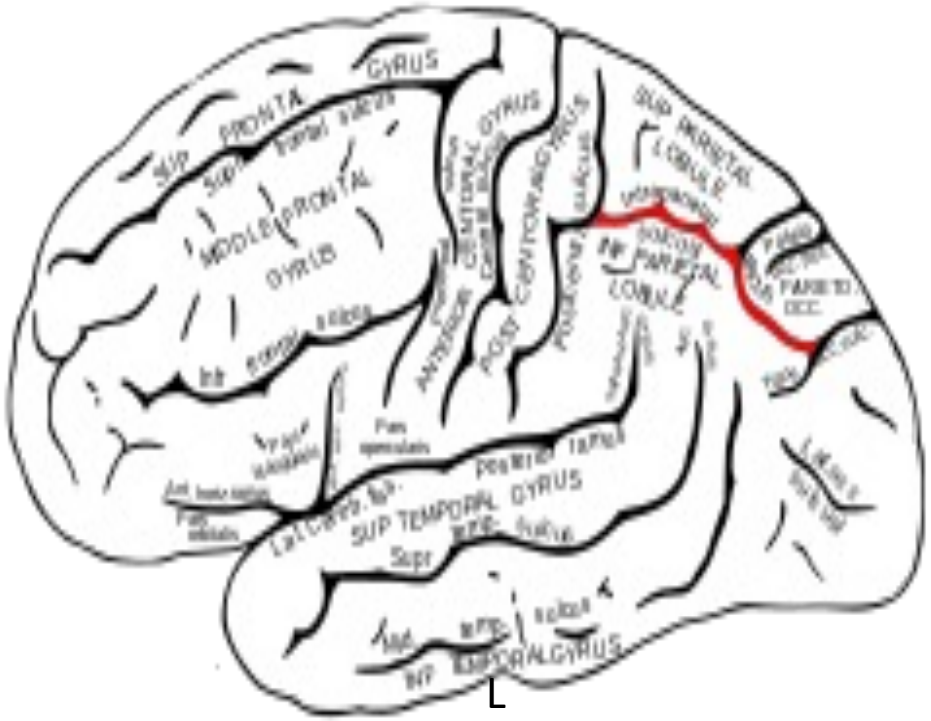
Language and General Semantic Regions

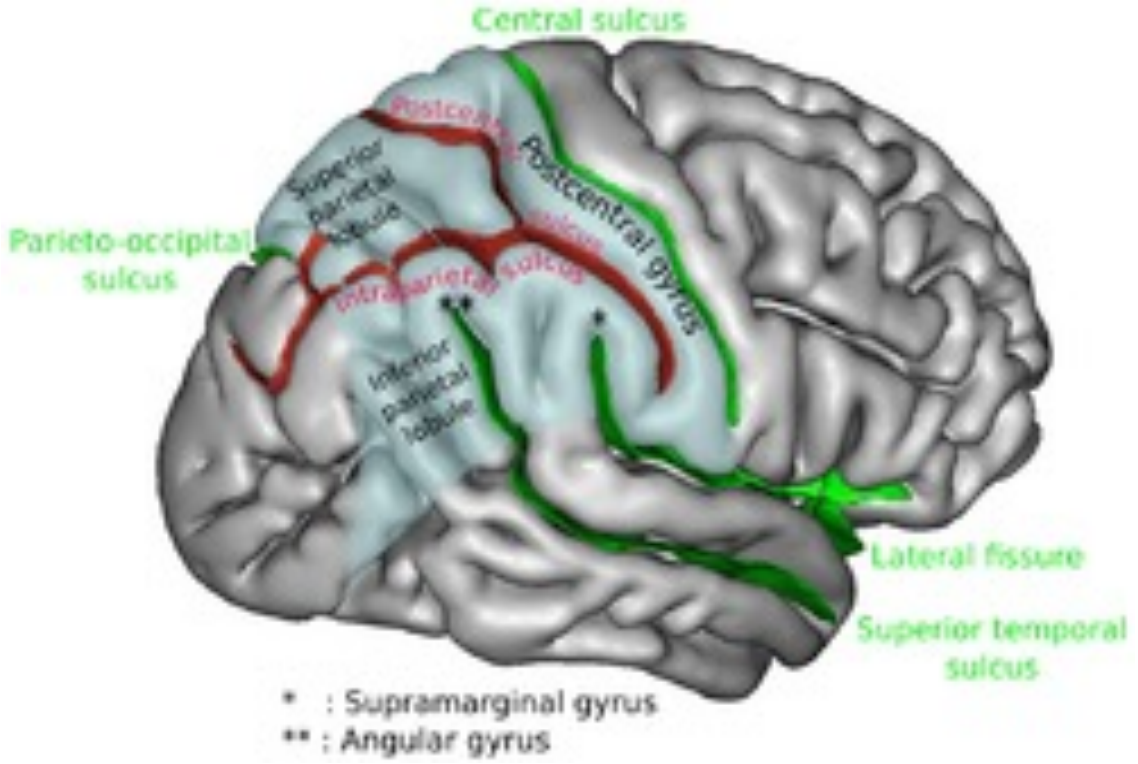


Parietal Lobe



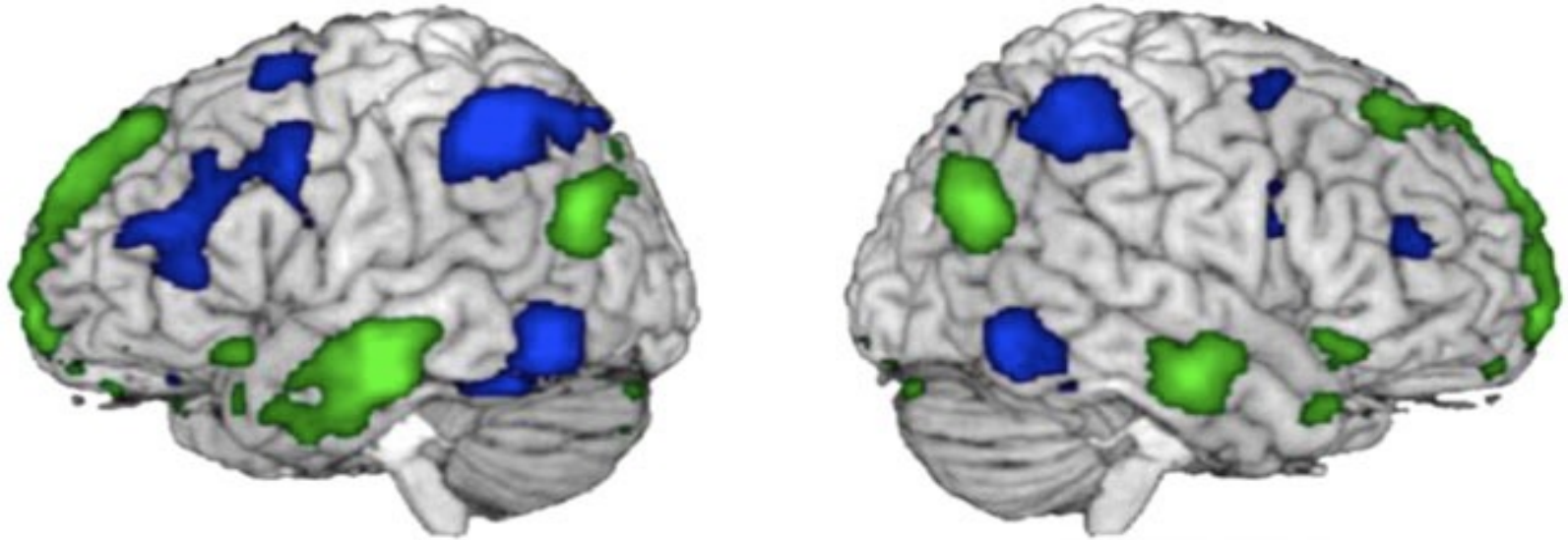
Intraparietal sulcus





Response of Mathematicians' Brains

'Lp spaces are separable' versus 'The Paris metro was built before the Istanbul one'



math > nonmath nonmath > math

MEG Confirmation